APPENDIX E

MAOP BACKGROUND AND HISTORY

DRAFT

Report

on

MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) BACKGROUND & HISTORY

March 5, 1998
(revised June/98 KGL)

For the

GAS RESEARCH INSTITUTE

By

Wesley B. McGehee
Pipeline Engineering Consultant
14405 Walters Road Suite 351
Houston, Texas 77014

DISCLAIMER

This report was prepared by Wesley B. McGehee, Pipeline Engineering Consultant. Neither Wesley B. McGehee nor any person acting on his behalf:

1. Makes any warranty of representation, expressed or implied, with respect to the accuracy, completeness or usefulness of any information contained in this report, including any warranty of usability or fitness of any purpose with respect to the report or that the use of any information, method, or process disclosed in this report may not infringe privately owned rights.

2. Assumes any liability with respect to the use of the report, or for any damages resulting from the use of any information, apparatus, method or process disclosed in this report.

TABLE OF CONTENTS

MAXIMUM ALLOWABLE
OPERATING PRESSURE (MAOP)
BACKGROUND
&
HISTORY

INTRODUCTION

This report presents information on the background and history of MAOP extending back to the early American Standards Association for pressure piping (ASA B31.1) issued in the 1930's, and following the evolution of MAOP's in the piping codes on up to the present time. This will be done to the extent that information is available.

OBJECTIVE

The objective of this study was to present information in a manner that can be a basis for future developments in the formulation of other factors and criteria in setting MAOP's. Some background is presented to show how the ASME B31.8 Committee developed and adopted the 80 percent stress level within the Code.

APPROACH

In order to develop the background and history of the MAOP's presently in the ASME B31.8 Code for Gas Transmission and Distribution Piping Systems, I made an in- depth search of my own files, applicable literature, previous research, and my own experience within the ASME B31.8 Committee. The focus of this study was the origin of the 72 percent SMYS, class location safety factors, and the 80 percent SMYS.

BACKGROUND

The code for natural gas pipelines began in the U.S. as a part of the American Standards Association Code for Pressure Piping, ASA B31.1. This code was originally published in 1935 as an American Tentative Standard Code for Pressure Piping covering Power, Gas, Air, Oil and District Heating. Following the incorporation of Refrigeration to the scope, ASA B31.1 was published as the American Standard Code for Pressure Piping in 1942.

After this time there were additions and/or supplements published in 1944, 1947, and 1951. In all these publications the gas code was characterized under Section 2, Gas and Air Piping Systems. In 1952, the code was subdivided and the gas code became the Gas Transmission and Distribution Piping Systems Code, issued as ASA B31.1.8. This document incorporated material from Sections 2, 6 and 7 of the 1951 Edition of the Pressure Piping Code, making it a stand alone code.

In 1952 a new committee was organized to write code material for the new Section 8. This committee was chaired by Fred A. Hough (Ref. 1). The committee was charged to develop code material to reflect new materials and methods of construction and operations. This group made many changes including design philosophy for the class location concept. This material was incorporated and published in ASA B31.1.8 in 1955. In 1958 further revisions were published in ASA B31.8. Since that time the Section 8 Code Committee has published revisions in 1963, 1966, 1967, 1968, 1975, 1982, 1986, 1989, 1992, and 1995.

This report will show the concepts used to develop the Maximum Allowable Operating Pressures (MAOP's) for the various Editions of the Code.

HISTORY

Origin of 72 Percent of the SMYS

The appropriate MAOP for pipelines was one of the fundamental matters that had to be resolved. The committee needed to find some basis for establishing the MAOP for pipelines. Many operators felt that the MAOP should be based on a test pressure. The problem was that pipeline operators were utilizing a wide variety of field pressure tests. Some operators were testing pipelines to 5 or 10 psig over operating pressure. One reason for these relatively low test pressures was that testing was done with gas. In order to establish a consistent basis for MAOP, the committee agreed that the mill test pressure would be used and the rule would apply to all pipe. Customarily the mill test was 90 percent SMYS. The committee agreed that to be consistent, the MAOP for cross country pipelines should be 80 percent of the 90 percent SMYS mill test, which would be 72 percent of the SMYS. The 72 percent SMYS first appeared in 1935 in the American Standards Association Code for Pressure Piping, ASA B31.1.

The 1951 Edition of the B31.1 Code (ASA B31.1.8), for cross country pipelines, included the 72 percent SMYS (80% of 90% mill test) and provided an equation to define wall thickness based on this maximum pressure and nominal wall thickness. This code further identified a lower stress for pipe in compressor stations, which was limited to a percentage of the 80 percent of mill test as a function of diameter of the pipe diameter which was: 22% for 0.405 inch OD (OD = outside diameter and smaller pipe, 49% for 3.5 inch OD pipe, 72% for 8.625 inch OD pipe, and 90% for 24 inch OD and larger pipe. Therefore, for large diameter pipe in compressor stations, percent of SMYS allowed would have been 90% × 80% × 90% hence 65% of SMYS. The only other indication of limit on MAOP was 50 percent SMYS inside the boundaries of cities and villages.

As mentioned previously, the gas code was first issued as a stand alone code in 1952 in ASA B31.1.8 Gas Transmission and Distribution Piping Systems under a new committee chaired by Fred A. Hough (Ref. 2). This committee was charged with the responsibility of maintaining and updating the code. Over a two and one half year period, this Committee developed the ASA B31.1.8 - 1955 Gas Transmission and Distribution Piping Systems Code. During this time the MAOP was one of the items that was considered. Prior to this time the gas transmission code limited the MAOP to 72 percent SMYS in all locations except "inside incorporated limits of towns and cities" and certain limits in compressor stations. The MAOP in these areas were limited as indicated above.

Some in this committee felt that MAOP should be based on the field test. Hydrostatic test, with a water medium, was done by some operators to much higher pressures than had been done in the past. However, other operators continued to conduct field testing to the lower pressures. For this reason, basing the MAOP on field test pressure was unacceptable to these operators. The acceptable solution was finally found in adopting the long established practice of using 80 percent of 90 percent mill test pressure for MAOP in cross country pipelines.
There was a realization by this Committee that there was a need to consider intermediate levels of pipeline stress levels based on population density and other special conditions.

Establishing Stress Levels For Class Locations

In 1955, the second edition of the American Standard Code for Pressure Piping, Section 8. ASA B31.1.8 - 1955 Gas Transmission and Distribution Piping Systems was published. This document was the first to designate four types of construction to be used based on population density. Prior to 1955, code editions permitted a maximum operating hoop stress of 72 percent SMYS in all locations except those inside the incorporated limits of cities and towns. In these areas a maximum hoop stress of 50 percent SMYS was specified. Between 1952 and 1955 the Section 8 Subcommittee realized that there was a need to delimit areas of population density and establish hoop stress limits below 72 percent SMYS that would be appropriate in each area to protect public safety. Many operators were reducing the stress levels below 72 percent SMYS in certain areas although there were no code criteria to indicate which intermediate stress levels should be used for the various degrees of population density. These operators had adopted various lower stress levels for population density areas, as well as road and railroad crossings, but the criteria were not uniform among operators.

In order to study and evaluate how population densities could be classified and appropriate hoop stress levels could be established, the Section 8 Committee formed a subgroup to address this problem. The subgroup elected to use a ½ mile corridor with the pipeline as the centerline and to establish areas of population density within the corridor in running miles along the pipeline. An aerial survey of many miles of existing major pipelines was conducted to see what percentage of these pipelines would be impacted by areas of population density where lower stress levels should be applied to enhance public safety. A consulting engineering firm was engaged to evaluate the results. Reportedly, at the time of this study, it was found that about 5 percent of the total pipelines surveyed would be impacted by population density requiring stress levels below 72 percent SMYS. The subgroup determined that the population density in the ½ mile corridor traversed by the pipeline should be evaluated according to a building count along both 1 mile and 10 mile sections to establish a population index to define hoop stress levels to identify type of construction in each area. From this study, it was determined that class locations based on a population density index was needed as follows:

Class 1, (72% SMYS) Sparsely Populated Areas
Class 2, (60% SMYS) Moderately Developed Areas
Class 3, (50% SMYS) Developed Residential and Commercial
Class 4, (40% SMYS) Heavy Traffic and Multistory Buildings

In addition, types of construction were established as follows:

Type A (72% SMYS)
Type B (60% SMYS)
Type C (50% SMYS)

Type D (40% SMYS)

The type construction identified the hoop stress allowed in certain locations. For example uncased highways and railroad crossing in a Class 1 (72% SMYS) location would require a Type B (60% SMYS) construction in the crossing.

It is important to note that the ½ mile corridor width selected to establish the population index was not selected as one that would be a hazardous zone in the event of pipeline failure. The ½ mile corridor was one of convenience because the width of typical aerial photographs at that time were conducive for the purpose and could be used to evaluate nearby activities that may impact the pipeline safety in the future.

The reason population density is of concern near the pipeline is that the greater concentration of the public results in greater activity which may cause damage to the pipeline. Some of these activities are trenching for water and sewer lines, terracing, cutting for streets and other digging in the proximity of the pipeline. The lower stress levels are used so that in the event of limited outside damage to the pipeline from these activities, the pipeline may not fail causing a hazard to the public.

This defined ½ mile corridor width remained in the Code until the 1982 Edition of ASME B31.8, at which time the corridor was reduced ¼ mile because experience had shown that activity from population density over 1/8 mile from the pipeline would not cause damage to the pipeline. Also when pipeline failures occurred, impact on people or property was minimal beyond the 1/8 mile half corridor width.

The Federal Regulations (49 CFR 192) were issued in 1970 as a result of the Pipeline Safety Act of 1968, by the Office of Pipeline Safety (OPS). Although OPS adopted much of the 1968 Edition of ASME B31.8, they reduced the corridor width from ½ mile to ¼ mile. This was done in a Notice of Proposed Rule Making (NPRM) in which the following was stated (Ref. 3):

> "A recent study that included hundreds of miles of pipeline right-of-way areas indicated that a zone of this width is not necessary to reflect the environment of the pipeline. A ¼ mile wide zone extending one-eighth of a mile on either side of the pipeline appears to be equally appropriate for this purpose. It would be an unusual instance in which a population change more than one-eighth of a mile away would have an impact on the pipeline. Conversely, an accident on the pipeline would rarely have an effect on people or buildings that were more than an eighth of a mile away. For these reasons, it appears that the density zone can be reduced from one-half to one-quarter of a mile without any adverse effect on safety."

Development of 80% SMYS MAOP

In the early 1950's testing equipment, procedures and technology were developed to test pipelines with water, and some operators began hydrostatic testing. These operators were safely testing to higher pressures with water in contrast to earlier more risky testing with gas. Some operators readily recognized the value of hydrostatic testing as a new tool to prove the integrity of the pipeline. Some operators were hydrostatically testing to 100 percent of the actual minimum yield strength as determined by steel mill metallurgical test.

One operator determined the actual minimum yield strength by hydrostatic test from the pressure versus volume plot. The pressure-volume plot was made by starting the plot below the mill test pressure to establish a straight line (below initial deviation). The actual minimum yield strength was determined when the slope of the line became one-half of the slope of the straight line portion of the plot. By using actual minimum yield strength, MAOP's much greater than 72 percent SMYS were established. This allowed a means to establish a known safety factor between MAOP and test pressure allowing pipelines to be operated at 80 percent SMYS or greater. In addition, essentially all defects present during the test that may fail at MAOP were removed by testing to actual minimum yield.

After approximately 16 years of research, study and testing to prove the value of testing to actual minimum yield, the technology was documented and published in the AGA REPORT L 30050, 1968 (Ref. 4). Many in the pipeline industry realized the merits of hydrostatic testing to actual minimum yield to:

1. Increase the known safety margin between MAOP and test pressure;
2. Prove the feasibility of operating safely above 72 percent SMYS with a greater known safety factor;
3. Remove defects that might fail in service; and
4. Improve the integrity of the pipe.

Based on this experience, a proposal was made to ASME B31.8 to allow operation of pipelines above 72 percent SMYS around 1966 - 1967. Unfortunately the proposal to allow the operation of pipelines at 80% SMYS received some unresolved negative votes which precluded inclusion in the 1968 Edition of ASME B31.8 and before the B31.8 committee could resolve the issue and amend the code the Pipeline Safety Act of 1968 was enacted.

In 1968, the Office of Pipeline Safety (OPS) adopted the 1968 Edition of ASME B31.8 as an interim safety standard until 1970 at which time OPS issued the final rules as Title 49 Code of Federal Regulations Part 192 (49 CFR 192). When issued, Title 49 CFR 192 was almost verbatim from the 1968 Edition of ASME B31.8, hence, the MAOP in Class 1 locations for pipelines installed after November 11, 1970 became 72 percent SMYS. Those pipelines built before November 11, 1970 operating above 72 percent SMYS could continue operating at those pressures if they qualified under the "grandfather clause" in the Federal Regulations. The "grandfather clause" essentially said that not withstanding all other requirements for establishing MAOP for new pipeline that:

> "... an operator may operate a segment of pipeline found to be in satisfactory condition, considering its operating and maintenance history, at the highest actual operating pressure to which the segment was subjected during the 5 years preceding July 1, 1970, or in the case of offshore gathering lines, July 1, 1976 ..." (Ref. 5)

This is subject to the requirements of change in class location.

The "Grandfather Clause" is for pipelines built before the Federal Regulations were issued. When a class location change occurs, that portion of the pipeline class location unit must meet the requirements of a new pipeline, i.e., pipelines under the "grandfather clause" which operate above 72 percent of SMYS would no longer be able to do so and no new pipelines constructed after the Federal Regulations were issued could be qualified above 72 percent SMYS.

After the Federal Regulations became effective, many operators failed to see a role for the ASME B31.8 in the regulatory environment. At this time the B31.8 committee essentially disbanded, however, in 1974 operators realized that unless code activities were resumed, pipeline technology would not advance beyond the 1968 Edition of ASME B31.8. It became apparent that unless the B31.8 code was maintained ASME would withdraw support and American manufacturers would be required to use foreign standards and specifications which might handicap them in the international arena. The B31,8 code is used in the Middle East, South America and many other international regions. In addition, American valve manufacturers and fabricators would be forced to build to foreign specifications in the absence of the ASME B31.8 Code which references U.S. specifications and standards. Consequently, the Code Committee met in 1974 and published the 1975 Edition to preserve the Code.

In the latter part of the 1970's, the proposal to allow pipelines to operate up to 80 percent SMYS was again submitted to the ASME B31.8 Code Committee. The Committee worked several years to develop criteria and requirements for the design, hydrostatic testing and ductile fracture control for pipelines to be operated up to 80 percent SMYS. The greatest opposition came from pipe manufacturing members of the Committee. The pipeline operator Committee members realized that transporting gas at 80 percent SMYS would be a great economic advantage, however, the pipe manufacturing members envisioned an economic loss in the sale of pipe. The use of an 80 percent SMYS greatly improves the utilization of pipe which would reduce the tonnage of pipe purchased. The Committee finally resolved all the issues involved in design, hydrostatic testing, and control of ductile fracture and approved provisions for pipelines to operate up to 80 percent SMYS. The allowance to operate pipelines to a maximum limit in onshore Class 1 locations was published in the ASME B31.8a - 1990 Addenda to the B31.8 - 1989 Edition.

CONCLUSIONS

The code for natural gas pipelines originated as an American Standards Association code for pressure piping. Committee members felt that the MAOP should be based on a pressure test, however, the operators were using a wide variety of field test pressures. In order to establish a consistent basis, the committee decided to use 80 percent of the 90 percent mill test, which was common to all qualified steel pipe. Thus, the MAOP for rural cross country pipelines was established as 72 percent SMYS and was published in the 1935 Edition of the American Standards Association Code for Pressure Piping, ASA B31.1.

The ASA B31.1.8 - 1955 Gas Transmission and Distribution Piping Systems was the first to designate class locations based on population density. Prior to this the previous code had allowed 72 percent SMYS for cross country pipelines and 50 percent SMYS for pipelines within the incorporated limits of towns and cities. The committee commissioned a study which indicated only 5 percent of the pipelines would require lower stress levels due to population density. The original corridor was set at ½ mile with the pipeline in the center line. The corridor was later reduced to ¼ mile in the ASME B31.8 - 1982 Edition. As a result of the study four stress levels were set, based upon increasing population density, which were defined as Class 1 (72% SMYS), Class 2 (60% SMYS), Class 3 (50% SMYS), and Class 4 (40% SMYS). Also four types of construction were identified to assign stress levels for fabrications, compressor stations, highway and railroad crossings in Class 1, Class 2, Class 3, and Class 4 locations.

Beginning in the early 1950's, hydrostatic testing was developing as a major tool to prove the integrity of the pipe. Some operators realized the value of testing pipe to actual minimum yield strength after many years of research and development, and some were using the actual minimum yield strength to determine MAOP. One operator actually used the determined actual SMYS to establish MAOP's in excess of 80 percent SMYS. Based on many years of research, testing and operational experience, the ASME B31.8 Committee developed code material for establishing an 80 percent SMYS MAOP. This provision was published in ASME B31.8a - 1990 Addenda to the B31.8 - 1989 Edition.

REFERENCES

5. Hough, Fred A., "The New Gas Transmission and Distribution Piping Code," *Gas*, Part 1: The History and Development of the Code, January 1955.

6. Hough, Fred A., "The New Gas Transmission and Distribution Piping Code," *Gas*, Part 5: Relating Design of Facilities to the Requirements of the Location, May 1955.

7. Hazardous Materials Regulation Board, "Establishment of Minimum Standards for Gas Pipeline Class Location Definitions," *Federal Register*, U.S. Department of Transportation, Title 49, Chapter 1, Parts 190 and 192, March 24, 1970, pp 5012-5014.

8. Duffy, A.R., et al, "Study of the Feasibility of Basing Natural Gas Pipeline Operating Pressure on Actual Yield as Determined by Hydrotest," A.G.A. Report L 30050, 1968.

9. Hazardous Materials Regulation Board, "Establishment of Minimum Standards," *Federal Register*, U.S. Department of Transportation, Title 49, Chapter 1, Parts 190 and 192, August 19, 1970.